and first comes to destructive action when the latter is sexually mature. Here we have a case of "definite periodicity in an infectious disease" explained clearly and naturally by actual peculiarities. The disease germs remain latent, and traces even are scarcely to be found. The attacked individuals are even stimulated in their growth, and are in advance of the sound ones—until suddenly at the time of sexual maturity the disease germs, hitherto concealed within, come into destructive operation.

In smut fungi, which do not live exclusively in the grains, but also appear and form smut beds in other parts of the plants, *e. g.*, in corn smut, the infection remains local. The fungous germs proceed to the development of smut in the sufficiently young parts of the plants only on those spots into which they have penetrated. The plants are receptive to the infection as long as young parts are being produced on them. Only when this is no longer the case, *i. e.*, when the plants are full grown, does the stage of immunity begin. To what extent the peculiarities in the smut fungi and smut diseases, which are now explained, may be of value for judgment upon similar occurrences in infectious diseases, especially in pathology, is self-evident.

In conclusion, I may be permitted to observe that seven years' labor was necessary to reach the conclusions on smut fungi and smut diseases given in my first address four years ago, and in this present one. The substance of this address is here made public for the first time as original work.

RIPE ROT OF GRAPES AND APPLES.*

By E. A. SOUTHWORTH.

PLATE XVI.

HISTORY OF THE FUNGUS.

Judging from the bibliography of the fungus of ripe rot and from the very scant specimens in the herbarium, it seems to have received four or five distinct names at the hands of three or more investigators. The fact that it varies greatly in its microscopic and external characters probably accounts for the vicissitudes of nomenclature through which it has passed, and for the fact that one authority has given it two and perhaps three names.

In 1854, M. J. Berkeley described and figured in the Gardeners' Chronicle a disease of the grape caused by a fungus to which he gave the name *Septoria rufo-maculans*. He describes the fungus as attacking ripe fruit and causing considerable destruction. From his figures and general description there is little doubt that the fungus is the same as

* *Glœosporium fructigenum*, Berk.

the one which is the subject of this paper. Later he changed the name to *Ascochyta rufo-maculans*, and it is described under the latter name in Saccardo's *Sylloge*, although Von Thümen in Fungi Pomicoli calls it *Glœosporium rufo-maculans*.

In 1856, in the same journal, Berkeley described and figured a fungus on apples under the name of *Glœosporium fructigenum*, and said:

> It was impossible not to call to mind the little fungus figured upon grapes, * * * and the subjoined figure compared with the one there given would at first seem to indicate an identity. But the spores were more inclined to be curved, rather longer, and not so variable in size, and the want of a perithecium separated the two widely from each other. * * * I would not affirm that the two productions are essentially different, and the more especially because in external appearance and habit they are so perfectly identical.

In the Gardeners' Chronicle for 1859 Mr. Berkeley describes a fungus on peaches and nectarines, *Glœosporium lœticolor*, as new to science. The description is not accompanied by figures, and it varies in some important points from that of the two preceding fungi, but in closing Mr. Berkeley says:

> A plant of the same genus destructive to apples is figured and described in this journal. We may also refer to the very similar production on grapes.

As we possess no specimens of *G. lœticolor* it is impossible to draw any conclusion as to whether this is or is not the same as *G. fructigenum*, but it does not seem impossible. The chief points of variation may be accounted for by the change of host.*

Still another fungus, or the same fungus under another name, was described by Berkeley and Curtis from South Carolina in Grevillea, in 1874, as attacking apples. They give it the name *Glœosporium versicolor*, and remark that "it is very different in habit from *G. fructigenum*, which also occurs on apples."

It is to be noted, however, that the specimen from which Berkeley described *G. fructigenum* was kept in the house, and if this was not the case with the fruit from which the other fungus was described there is a wide chance for variation, especially in a fungus which varies greatly even under the same conditions.

The herbarium of the Department gives very little aid in reaching any decision as to the identity of these fungi. There is one specimen labeled *G. fructigenum*, from Newfield, New Jersey, on rotting pears, but I am not sure as to the authority for its identification; and another of *G. versicolor*, from Delaware, which was distributed in Ellis and Everhart's North American Fungi, No. 1897, on apples. From a comparison of the two specimens there seems to be no doubt that they represent the same fungus. Of course it is impossible to form a decision which would be of any value from these premises, but it is evident that the

* W. G. Smith has recently figured a fungus on grapes which he calls *G. lœticolor*, and which from the figures seems to be the same as the *G. fructigenum* of this article.

descriptions given, if they do represent different fungi, are not sufficiently accurate to give us any criterion of identification.

In the Annual Report for 1888 Mr. Galloway described a fungus causing the bitter rot of apples, which he identified as Berkeley's fungus *Glœosporium fructigenum*, and which agreed closely with the herbarium specimens.

In the summer of 1888 Prof. F. L. Scribner found what he supposed to be a new fungus on the grape in the Department grounds. He examined it, but as its similarity to bitter rot of grapes threw some doubt on its specific value no further observations in regard to it were made. In the following season it was found again by the writer, and since then it has come to the Department from several sources.

A study of its structure at once suggested a close relationship with the fungus causing bitter rot of apples, and also with the one causing the bitter rot of grapes. It differs from the latter, however, in several points.

Owing to its similarity of form with bitter rot of the apple, a series of experiments was undertaken to ascertain whether or not the two were identical. Living spores of the grape fungus were inserted under the skin of healthy apples by means of a flamed knife, and other apples similarly punctured but not having the spores inserted were used as checks. At least twelve apples were thus infected, each apple being infected at three points. In every case but one the fungus developed, and with but one exception at all of the infected points. The one exception was where spores were used which a few days later were found to be incapable of germination. In case of another apple, spores were purposely used which were supposed to be past the power of germination. The result was that the fungus developed at one point of infection only, and this was probably the result of carelessness, as the knife was not flamed after being used to infect an apple with spores from another grape, and the spot into which the knife was first pushed received some of these spores that were capable of germination. None of the checks developed the fungus. The rot spots began to appear in about 3 days, and pustules made their appearance in from 5 to 8 days.

Apples attacked by the typical bitter rot fungus were obtained from Arkansas, and the spores were used for infecting grapes in a manner similar to that described for apples.

The results were not so striking as in the former case, but in a small proportion of the infected grapes typical pustules with spores were developed, and this was not true of the checks. Many of the infected grapes, which did not show pustules, decayed in a manner typical of grapes attacked by the fungus, but grapes were so much harder than apples to preserve from the attacks of saprophytic fungi that in most cases they succumbed to these before the *Glœosporium* had a chance to complete its development. The most successful infection experiments

were made on Malaga grapes, three or four berries out of a dozen developing the fungus, but grapes grown on the grounds were also successfully infected.

The pustules produced by inoculation were exactly like those produced in a state of nature, and the fungus in apples infected with spores from another apple was exactly the same, both as to structure and effects produced, as in apples infected with spores taken from the grape.

These experiments leave no doubt that the fungus found here on the grape is the same as the bitter rot of apples. And from a comparison of Berkeley's figures and description there is very little doubt that it is identical with his *Ascochyta (Septoria) rufo-maculans*. The strict law of priority might demand that we now make the specific name *rufo-maculans*, but since the better known *G. fructigenum* is also Berkeley's name it will remain so in this paper. It is perhaps well to say that Professor Cavara has kindly compared this fungus with the *Tubercularia acinorum* described by himself and states that the two are distinct.

The proper settlement of the whole question depends upon the comparison of type specimens not accessible to us, and it is hoped in what follows to give a sufficiently full description of the fungus so that others who have these specimens within reach may be able, by comparing them with the figures and descriptions, to decide whether they represent distinct species or not.

The popular name which should be given to the disease on both grapes and apples is nearly as much of a question as that of the scientific name of the fungus. The old term, bitter-rot, so applicable to the disease of the apple, will not do for the grape, as the fungus does not give the latter fruit any bitter taste, and the name is already given to another grape-rot, caused by a fungus, which does impart a decided bitterness to the ripe berry. The term anthracnose is also preëmpted, otherwise that might be used, as this fungus belongs to the same type as others causing this disease. The name ripe rot, which has been finally adopted, may answer the purpose in spite of its lack of euphony, as the fungus attacks neither grapes nor apples until they begin to ripen.

EXTERNAL CHARACTERS.*

On the apple.—The presence of the fungus is first indicated by one or more brown spots somewhere on the surface of the apple. These may not be more than a quarter of an inch across at first, but they spread very rapidly and in time cover the whole apple. The spots have the appearance of ordinary decay except that they are a little sunken, and are apt to be somewhat firmer than is natural where this fungus is not present. Moreover, after the spot has existed a few days, small black pustules make their appearance on the surface. These are often so numerous in the center as to give it a black color, and those nearer

* Colored drawings of the external effects of this fungus will appear in the Annual Report for 1890.

the circumference are likely to be arranged in circles. It not infrequently happens that the pustules are not black at first, especially when the apples have been kept in a moist environment. They may appear quite white before they break through the cuticle, and later the spore masses give them a pink color over the top. Sections through diseased apples show that the tissues are decaying for some distance; and in preparing a partly decayed fruit for eating, great care must be taken to remove every fragment of this discolored tissue, as a scarcely perceptible amount can impart an intensely bitter taste.

On the grape.—The fungus seems to attack only ripe grapes, and when the diseased grape is a purple one no change of color occurs, but the berry decays and the skin seems to be raised up in pustules over the diseased portions. On white grapes the fungus produces a very characteristic appearance. A small, reddish-brown spot appears on the side of the berry; this spreads and becomes darker in the center, so that by the time it has spread over half the berry it has a purplish center merging into a narrow bright-brown border. It is moreover covered with minute pustules which are at first whitish, then exude a flesh-colored powder, and finally become dark brown or even black with age. The berry finally becomes quite dry and shriveled, but even in this condition it does not become black like those attacked by black rot, but may even preserve a translucent appearance. On a few grapes, whose tissues were at the same time hardened by the presence of the mycelium of *Peronospora viticola*, the areas attacked by the *Glœosporium* had sunken in, as is the case with the apple. On the grape the pustules often continue bearing spores, and hence retain their flesh-colored appearance even when the berry is nearly all dried up. The fungus does not communicate a bitter taste to this fruit.

MICROSCOPIC CHARACTERS.

The structure of the fungus is so variable that it is almost impossible to frame a description that will be true under all circumstances.

The appearance of the fruiting bodies differs on nearly every berry that the fungus attacks, although it is a somewhat curious fact that the pustules on any one berry are very nearly alike. The color and shape of the spores are the most constant characters, but the latter varies considerably. In the following description the most characteristic and common variations will be noted, but they by no means comprise all that may be expected even in a short study of the fungus.

The first stage in the formation of the fruiting body is the most constant one. A cushion of stroma forms just below the upper wall in a group of the epidermal cells; as it increases in size the contents and lower wall are pushed downwards, the cross walls are broken or absorbed, and the upper wall pushed upward until it is ruptured and the fungus exposed to the air. As soon as the stroma has attained about 20μ in thickness it can be seen to consist of parallel threads arranged at right angles to

the plane of the epidermis, and containing frequent septa. The stroma mass is colorless at first and shaped like a double convex lens. The hyphæ composing it are adherent along their whole course and may branch. The central portion is often composed of larger, more transparent hyphæ. When the cuticle is finally ruptured the shape of the stroma may change considerably, from the fact that it meets no further resistance to its upward growth. It is also from this time on that the changes which cause the fungus to be so variable take place. Sometimes the free ends of the hyphæ bear spores over the entire surface so that the stroma forms a compound sporophore, but usually the large cells comprising the center of the stroma mass break down, and the entire center becomes separated from the outer portions and may pass out through the opening in the cuticle. In this case spores are borne around the circumference of the stroma and the cavity left in the center develops basidia and spores on its sides, thus producing a pseudopcynidium. The amount of the stroma that disappears after the cuticle is ruptured varies exceedingly. In some cases the original mass seems to remain and grow dark colored. In other cases a large amount of stroma still remains, but it becomes dark colored, and enough of the original mass has disappeared so that the spores are borne on a very concave surface. The stroma grows dark colored as soon as the cuticle is ruptured, but the lower part of the central portion usually remains colorless except in very old pustules. In some of these, especially on the apple, it looks as if the stroma had greatly increased in quantity and in a measure at least lost its spore-bearing property. Whether this apparent increase is due to a growth from the base of the stroma has not been directly observed, but from the appearance of the sections this conclusion is almost irresistible, and the fact that the base often remains colorless below the center supports such a view. Examples of this are frequent on the grape, but on the apple the older dark-colored pustules are especially large and after a time seem to stop forming spores. When kept for a long time in a moist environment the ends of the hyphæ sometimes grow out into long dark-colored filaments.

Besides these more common forms there are cases where the stroma almost completely disappears after the cuticle is ruptured, and the result is a typical Glœsosporium form, viz, rather long basidia borne on a thin stroma and bearing oblong spores at their free ends. Still another case was found where, instead of a true stroma, the hyphæ were independent down to the very thin, irregular layer of pseudo-parenchyma always at the base of the parallel threads; thus forming extraordinarily long basidia with spores at their ends.

Spores.—The spores are unicellular but may become two or even three celled at the time of germination. They are colorless singly but flesh colored in mass, irregularly oblong, sometimes curved and often pointed at one end, or even ovate. They vary greatly in size as well as in shape, and in the case illustrated in Fig. 4 are much longer than

usual. They are apt to be shorter and thicker on the apple, and in dry than in moist surroundings.

Mycelium.—The mycelium is septate and branching, usually colorless, but may become darker colored with age. It is both intra and inter cellular, preferably the latter. In the apple it is sometimes so thick just below the epidermis that it nearly forms a continuous sheet, the threads lying parallel side by side.

The spores begin to germinate in water in about six hours. They swell considerably. The vacuole disappears, but the spore contents pass into the germ tube and the spore is either left partially empty or filled with very thin, slightly refringent protoplasm.

In several germination experiments secondary spores were produced in large numbers. What the conditions were that decided their appearance could not be determined. They were produced both in nutritive media and water, but seemed to be especially numerous where the ends of the hyphæ came in contact with some hard substance like the cover glass, and in two cases the addition of an extra drop of nutritive medium had the effect of stopping their formation. They may be formed on the end of the germ tube when it is no longer than the spore itself, and as the mycelium becomes better developed nearly every branch may produce a secondary spore on its end. They are developed as simple, colorless expansions of the end of the tube, which soon becomes delimited from the rest of the hypha by a septum. The walls become thickened and dark colored, the contents nearly transparent, and a bright spot, strongly refracting, like an oil globule, makes its appearance in the center. The mature spore has a very faint olive tinge and is nearly ovate in outline, being truncate at the smaller end on account of the septum which cuts it off from the hypha. They only retain their original regular form for a short time, the walls soon pushing out in all directions, thus forming a very irregularly lobed body. Sometimes these secondary spores send out a germ tube, and when this happens the bright spot disappears and the spore becomes lighter colored, the contents having apparently been exhausted. More often, however, the mycelium branches just below the point of insertion of the secondary spore, and even in this case the latter sometimes undergoes the changes just described.

The contents of the growing mycelium are at first granular, later becoming more homogenous, and by the time they have reached the stage illustrated in Fig. 7*b* occasional vacuoles make their appearance. Septa are formed soon after germination.

Setæ.—In a few cases brown setæ have been found in the pustules, both on the apple and on the grape, but mostly on the latter. They do not seem to be sufficiently constant or numerous to characterize the species. Where found they are two or more in a pustule, are septate, and of varying length.

Except for the shape and color of the spores this fungus would seem from the description to be identical with that of bitter rot of grapes

(*Melanconium fuliginea*, (S. & V.) Cav.) but there are several points of difference. The spores of bitter rot are navicular and fuliginous, and the stroma is made up of smaller and more uniformly dark-colored cells; moreover it does not seem to be as variable as that of the ripe rot, but there is a more regular disappearance of the upper central portion of the stroma, leaving a cavity the sides of which are always lined with spores and basidia. The formation of secondary spores has never been observed for the Melanconium and the mycelium proceeding from the spore is very different from that of the Glœosporium and is fuliginous. It does seem, however, as if the two fungi ought to be placed in the same genus, but it is not the purpose of this paper to make any changes in nomenclature.

Later stages.—In the Annual Report for 1887 Mr. Galloway described a stage which seemed to be an immature pycnidium. In hopes of obtaining more definite results in this direction, a number of apples which showed numerous characteristic pustules were placed under bell jars in the fall and left until midwinter. When examined, the stages figured in the annual report were found; but in some cases the fruiting body was composed of one outer layer of dark-colored cells, those inside being colorless, and the contents of the central ones broken up into small particles. The structure of the entire body closely resembled that of the immature pycnidia of black rot of grapes, the colorless cells being isodiametric and nearly hexagonal. No spores could be seen, but in one or two cases the contents of the conceptacle were not fully distinguishable, and seemed to be partly composed of radiating lines passing from the circumference to the center. From the top of these bodies arose the characteristic stroma mass, or rather, in this case, a compound sporophore, bearing spores at the free ends of the hyphæ. Still later, one conceptacle showed two asci containing partly developed spores. Unfortunately, the apples were so overgrown with Penicillium and so putrid from the attacks of insect larvæ and bacteria that they had to be thrown away before any more definite results could be obtained.

ECONOMIC NOTES.

The fungus has been known on the apple for a long time, Berkeley's first description of it dating back to 1856. During the past five years it has proved very destructive in certain localities especially in the South and Southwest. One fruit grower from Arkansas reported that from the effects of the rot in the summer of 1887 his orchard of seventy-five trees would not yield 25 bushels. Until the present season only solitary cases have been known of the fungus attacking the grapes, but during the past summer we have received specimens from Connecticut and New York. In the latter State it was observed in Wayne, Cayuga, and Seneca Counties and was found on grapes sent in from the grape-growing district in the southeastern part of the State. It seems to be slowly spreading on the grape, and attacks the fruit often after it is

stored in crates preparatory to sorting. It seems to spread in these large crates, and was found in the most active stage as forming a large per cent of the cullings from the packers.*

Thus far it has been by no means a serious enemy to the grape, but the chief danger for the future seems to lie in the fact that it has proved so formidable on the apple and that the grape can not be considered as safe from its attacks if apples in the vicinity are diseased.

It attacks neither fruit until the ripening process has begun, and with the apple as with the grape may develop and spread after they are packed and stored.

Treatment.—From the foregoing it is evident that it is of great importance to carefully cull all fruit among which the presence of the disease is suspected, as a diseased fruit may infect the healthy ones that lie in contact with it. It has been shown, however, by one experiment, that this disease can be almost wholly avoided by the use of fungicides.

In the summer of 1888 the Department commissioned Mr. Geo. Curtiss, of Stafford County, Virginia, to make a trial of certain fungicides in the prevention of the disease. Mr. Curtiss had repeatedly lost all of certain varieties by this fungus, and his orchard offered a good field for experiment. In order to make the value of the remedies used perfectly clear he left some of the trees unsprayed, and in one case he sprayed only half of a tree, leaving the other half unsprayed as a check. The remedies used were potassium sulphide (one-half ounce to a gallon of water) and the ammoniacal copper carbonate. The sprayings were not begun until August 18 for the potassium sulphide, and August 27 for the copper carbonate, too late in both cases for the best results, as the disease had already made considerable progress. But even under these unfavorable conditions the result was very marked. The apples that were not diseased at the time of spraying were perfectly protected, while the unsprayed trees dropped all their fruit. On the tree that was half sprayed the difference between the two sides was as marked as between the sprayed and unsprayed trees. If the spraying had been done a month earlier it is reasonable to suppose that with proper care in application the rot could have been almost entirely prevented.

Where copper remedies are used for black rot or mildew it is not likely that the grapes are in danger from the ripe rot, and in cases where no remedies have been used, two or three sprayings will probably protect the grapes. For this it will not be necessary to go to the expense of preparing the Bordeaux mixture, but the ammoniacal solution or even the potassium sulphide will probably be satisfactory.

* See Diseases of the Grape in Western New York. Journal. Vol. VI, No. 3, p. 99. Referred to as the Grape glœosporium.

SOUTHWORTH ON RIPE ROT OF GRAPES AND APPLES.

BIBLIOGRAPHY.

Berkeley, M. J. *Septoria rufo-maculans.* Gardeners' Chronicle, 1854, p. 676.
———. *Ascochyta rufo-maculans.* Outlines of British Fungology, 1860, p. 320.
———. *Glœosporium fructigenum.* Gardeners' Chronicle, 1856, p. 245.
———. *Glœosporium lœticolor.* Gardeners' Chronicle, 1859, p. 604.
——— and Curtis, M. A. *Glœosporium versicolor.* Grevillea, Vol. III, p. 13.
Curtiss, G. C. *Treatment of bitter rot of apple.* Section of Vegetable Pathology, U. S. Department of Agriculture, Bulletin 11, p. 38.
Ellis, J. B., and Everhart, B. M. *Glœosporium versicolor,* B. and C. Journal of Mycology, Vol. I, p. 112.
Galloway, B. T. *Bitter rot of the apple.* Annual Report U. S. Department of Agriculture, 1887, p. 248.
———. *Sulphuret of potassium for bitter rot of apples.* Journal of Mycology, Vol. V, p. 37.
———. *Bitter rot of apples.* Section of Vegetable Pathology, U. S. Department of Agriculture, Bulletin 8, p. 61.
———. *Bitter rot of the apple.* Annual Report U. S. Department of Agriculture, 1889, p. 412.
Saccardo, P. A. *Ascochyta rufo-maculans,* Berk. Sylloge, Vol. III, p. 395.
———. *Glœosporium fructigenum,* Berk. Sylloge, Vol. III, p. 718.
———. *Glœosporium lœticolor,* Berk. Sylloge, Vol. III, p. 718.
———. *Glœosporium versicolor,* B. and C. Sylloge, Vol. III, p. 718.
Smith, W. G. *Glœosporium lœticolor,* Berk. Gardeners' Chronicle, 1890, p. 657.
Von Thümen, F. *Glœosoporium rufo-maculans* (Berk.), Thum. Fungi Pomicoli, p. 59.
———. *Glœosporium versicolor,* B. and C. Fungi Pomicoli, p. 60.
———. *Glœosporium lœticolor,* Berk. Die Pilze des Aprikosenbaumes, p. 6.

DESCRIPTION OF PLATE.

FIG. 1. Stroma mass broken through the epidermis. Drawn from specimen, soaked in potash, which caused the ends of the hyphæ to swell and the spores, if there were any, to fall off.
FIG. 2. A later stage. The central part of the stroma mass has begun to break down and spores to form around the circumference.
FIG. 3. Still later stage in the same process.
FIG. 4. Glœosporium form of fungus.
FIG. 5. Spores; three on basidia.
FIG. 6. Setæ.
FIG. 7. Germinating spores; some producing secondary spores on hyphæ.

ANTHRACNOSE OF COTTON.*

PLATES XVII, XVIII.

By GEORGE F. ATKINSON.

While investigating the disease of cotton popularly called "black rust" and "red rust," I found upon an old leaf scar of a cotton stalk a fungus, the spores of which in mass are of a roseate tint. The spores were produced in small clustered heaps, which at length broke through

* Paper read before the American Association of Agricultural Colleges and Experiment Stations. Champaign, Ill., November 11–13, 1890.